Bridging the gap: a novel approach to mathematics support

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Abstract

The ever growing gap between secondary and university level mathematics is now becoming a major concern to higher education institutions. The increase in diversity of students' background in mathematics, from students who have studied the more traditional A-level programmes to students with BTEC or international qualifications and part-time students who have been out of education for long periods, means that they are often unprepared for the marked shift in levels and catering for all abilities is difficult in the normal lecture, tutorial format. Lack of sufficient mathematical knowledge not only affects students' success on courses but also leads to disengagement and thus a high drop-out rate in the first 2 years of study. Many universities now offer a maths support service in an attempt to overcome this but their success is varied. This paper presents a novel approach to maths support designed and adopted by the University of Lincoln, School of Engineering, to bridge this transition gap for students, offer continued support through assessment for learning (AFL) and Individual Learning Plans (ILP's) and ultimately increase student success, engagement and retention. The paper then extends this proven approach and discusses proposed enhancements through the use of on-line diagnostic testing and implementation of a 'student expert' system to harness mathematical knowledge held by those gifted and talented students often overlooked by higher education institutions and to promote peer-to-peer mentoring. The paper shows that with the current support system in place, there is a marked increase in student retention, compared with national benchmark data, and an increase in student engagement and success measured through student feedback and presented retention data.

1. Background

Since 1990, it has been argued that the level of mathematical knowledge of students entering higher education has declined and that this shortfall not only impacts on their success but also significantly affects student engagement and retention. Around 28,000 full-time and 87,000 part-time students who commenced their studies in 2004-2005, were no longer in Higher Education in 2005-2006. A review of STEM education carried out by Sir Gareth Roberts in 2002 [1] showed that students can experience difficulty in making the transition from mathematics A-level, and that this has an impact not only on student success but also on the number of students opting for technical disciplines at universities. With the known shortfalls in students opting for STEM subjects and, in terms of engineering, an estimated shortfall of around 70,000 undergraduates in the power and energy sector alone, the need to put effective measures in place to aid this transition is now apparent.

These considerations are at the forefront of thinking in subjects with some level of mathematical content, and many institutions now have a maths support system in place. Universities do tend to recognise the fact that students are entering higher education with a lower level of basic mathematical skills, and also recognise the ever-increasing diversity in cohorts, from students who have studied more traditional A-level's to those with BTEC or international qualifications, and work-based learners. One way to address these issues is with a structured approach to mathematics support. With the government's increasing focus on channelling students through the vocational qualification route, the potential for universities to lower entry requirements to meet the demands of the rise in tuition fees and with industry keen to develop its workforce in order to compete within global markets, the need for more effective mathematics support will become even more significant in future.

In a 2001 study, a total of 95 UK Higher Education Institutes were asked if they provided any kind of maths support. Out of these 95, 46 indicated that they provided maths support whilst 49 indicated that they did not. "*The key element of this provision, which was identified most often by respondents, was the availability of one-to-one support*." This study was updated in 2004 and it was noted that out of 106 UK Universities there were still some 35 that did not provide mathematics support [2]. A further study reported in 2012 showed that out of 103 responding UK Higher Education Institutions, 88 now have some form of mathematics support system in place [3].

Engineering disciplines are underpinned significantly by mathematics and a lack of knowledge in the basic mathematical skill areas has a profound impact. It was found that students who lacked basic mathematical knowledge, and in particular part-time students who may not have undertaken formal studies for many years, were much more likely to not only under achieve in the stand alone mathematics modules but also in the other 'engineering science' modules that are underpinned by these mathematical principles [4]. This lack of understanding has the potential to force students to focus on grasping and improving their fundamental mathematical knowledge alone often leading to disengagement in subjects where mathematics is important, but less apparent.

This problem with a fundamental lack of mathematical understanding is experienced across the sector and, to some extent, across the globe. Many universities have put maths support systems in place, for example, by the way of drop in centres, extra lectures, maths clinics, publishing self-directed study materials, but the problems persist. For example, Mac an Bhaird [5] noted that the majority of students who were identified as having significant difficulties chose not to attend a centralised maths support centre, and within science subjects, only 33% of the at-risk students attended more than once (see also [6]). Similarly, Patel and Rossiter [7] noted that 40% of engineering students did not know there was a central maths support service within their institution, and 54% knew of the service but didn't use it.

So, the question is, how do we continue to provide and develop these mathematics support strategies in a way that is providing individual students, with very diverse backgrounds in both mathematics and engineering, with the best chances of success? This is a question that this paper seeks to (at least in part) address.

2. 'Bridging the Gap' – Transition Support

The first question that should be asked when faced with delivering material at any level is, what fundamental knowledge will the students need during its delivery and how can we check if they already possess that knowledge? This is frequently achieved to some degree by the use of a mathematics diagnostic test that students would complete prior to the start of the first academic year, but there are often three problems that arise from this approach. Firstly, the content of the diagnostic test is such that the only question it succeeds in answering is how strong or not a student may be in basic mathematics and not necessarily the basic mathematics that they require. Secondly, the test results are not used to inform any sort of learning plan for students meaning that valuable information about students' mathematical knowledge is not put to best use. Thirdly, students are often asked to take a diagnostic test without any preparation and this very alien experience may bias the test scores. In many cases, however, this strategy is quite deliberate as the purpose of the diagnostic test is to assess a student's embedded mathematical skills and not what they can achieve after preparing for a test. This paper describes a much more structured and informed approach that attempts to address and extend two of the recommendations set out in a report issued by the UK Engineering Council [8]:

1. Students embarking on mathematics-based degree courses should have a diagnostic test on entry.

2. Prompt and effective support should be available to students whose mathematical background is found wanting by the tests.

In the approach used at Lincoln, the content of the diagnostic test is driven by fundamental mathematics skills required for the student's first year of studies both in terms of stand-alone mathematics modules and other core disciplines. These topics are not on the syllabus as discrete subjects. For example, the study of vector algebra relies heavily on knowledge of basic trigonometry; therefore, the diagnostic test focuses on trigonometry rather than vector algebra. Through careful selection of the content, the diagnostic test provides much more insight into students' mathematical knowledge. The results are used to design Individual Learning Plans (ILP's) for students who showed weaknesses in these fundamental areas, and the ILP includes the opportunity for targeted mathematics support-sessions, rather than attendance on a general programme. This tailor-made approach avoids the pitfall of assessing to a threshold where only the students falling below some particular score level receive targeted support. The use of ILPs means that opportunities to support learning can be offered to all students including those who would have been neglected in a threshold process. Lincoln students have reported that this method has had a profound effect on their confidence, and has allowed students to focus on the main delivered material rather than being hindered by their lack of basic mathematical knowledge.

3. Continued Support Through Assessment for Learning (AFL)

Following the results from the diagnostic test and the implementation of ILP's for students, the approach adopted by the Lincoln School of Engineering then applies the Assessment for Learning (AFL) approach.

AFL is a strategy adopted mainly in Schools to inform student's learning and to improve the rate at which students' progress. "*Assessment for learning is the process of seeking and interpreting evidence for use by learners and their teachers to decide where the learners are in their learning , where they need to go and how best to get there*" [9]. The strategy outlines 3 major aims that are easily transferable to the way assessment is approached in Higher Education:

- Every student knows how well he or she is performing, they understand what they need to do to improve, and they know how to make that improvement. In order to achieve this they must have the correct support in place.
- Every teacher is equipped to make well-founded judgements about students' attainment, they understand the concept and principles of progression, and they know how to use their assessment results to forward plan; particularly for students who are not fulfilling their potential.
- Every institution has structured assessment systems in place that are used to make regular, useful, manageable and accurate assessments of student learning, and for tracking their progress.

The mathematics support approach adopted at Lincoln pays particular attention to these points in terms of assessing students' progress, making students aware of what is required of them and putting the appropriate measures in place to ensure that they are given adequate support as well as to be able to identify for themselves that they are continuously improving.

The progress of individual students is monitored during lectures and tutorial/seminar sessions using well known AFL techniques such as explicit learning objectives, random questioning, levelled exam style questions and immediate student feedback. Students' ILP's are continuously updated and followed up by targeted invitations for students to attend the relevant mathematics support sessions. This also allows the mathematics support to be extended to those Gifted and Talented (G&T) students who would normally be overlooked by the traditional support system in Higher Education. This in turn improves understanding and success within mathematics and other core disciplines.

4. Evaluation of the Current System

The success of this approach has been measured in relation to three areas; success, engagement and retention. The overall success of this approach can be readily measured through retention data but success and engagement have a large influence on this primary measure. Comparisons have been made between the data for the Lincoln School of Engineering and the KIS Engineering Benchmark Data. It was found that the percentage of young entrants to full-time degree courses in 2008-09 who withdrew from their studies was 8.8% for engineering courses compared to 6.5% for all subjects. This included students with significantly higher entrance qualifications than our own entrance qualifications equivalent to 280 points. Our retention rate in this category was 100%, i.e. all Lincoln Engineering students continued with their studies. This picture is also reflected more graphically among the percentage of mature entrants to full-time degree courses in 2008-09. Within this category, it was noted that 15.8% of mature engineering students abandoned their studies compared with 12.9% for all subjects. At Lincoln, the percentage of students who withdrew was only 5%. Student success is backed-up by these retention figures as, of the students who withdrew, 100% had achieved sufficiently high scores to progress, and so their decision to leave was not motivated by under-achievement.

Student engagement has been measured through formalised student feedback opportunities that are administered once per fortnight. The feedback gained from students showed that subjects underpinned by mathematics received high scores in the areas of understanding and interest. This level of satisfaction was confirmed within discussions between students and their personal tutors as well as academic tutors. Anecdotal evidence showed that students increasingly reported that their underlying knowledge of the fundamental mathematical principles continually improved with further engagement with the maths support system, and that this allowed them to focus their studies on the material being taught.

5. System Enhancements

The current system, is highly successful, but may be difficult to sustain as the School and hence cohort sizes grow. To this end, a series of system enhancements have been identified. These enhancements will build on the current system and will continue to allow for accurate diagnostic assessment. The enhancements will also serve as a method of identifying the sustained support requirements of individual students throughout their studies. The implementation of these enhancements will also allow the maths support methodology to become robust enough to engage students studying on any programme with mathematical content across the whole institution rather than just within the School of Engineering.

5.1 On-Line Diagnostics

Traditional AFL strategies have been designed around the group sizes of approximately 30 learners that would be found in a school or college setting. Although these can still be implemented within the typically larger HE class sizes, their effectiveness will decrease and they become very labour intensive. The system proposed here uses on-line diagnostics as a way of tackling this problem.

The on-line diagnostics are a series of test questions designed to cover those topics as identified by the appraisal of fundamental skills (section 3), along with a series of test questions covering new taught material. Questions are designed such that they match the topics that students can expect to encounter in an exam situation and are separated in to two distinct levels: Mathematics exams set by the School of Engineering are broken down into two parts; A and B. Section A covers generic type questions that require only knowledge of the process and require no application to a specific engineering problem. These are called Level 1 questions and would represent a pass standard. In order for students to gain marks towards higher degree classifications, they must demonstrate that they can apply this knowledge to a specific problem. This requires a higher-order skill according to Bloom's taxonomy [10] and these are referred to as Level 2 questions.

Tests will be administered following each taught topic and students will be assessed against specific learning objectives aimed explicitly at these two levels. This informs students about their current level and the work required in order to achieve the next. This information is contained within each student's ILP which is continually updated and monitored throughout their first year of studies. As the system is fully integrated with the student database, it is able to automatically update students' learning plan after each completed test meaning that there is no extra work involved for teaching staff and students obtain immediate feedback on their performance. Support is then offered via numerous on-line resources, through additional timetabled support sessions, or by a student mentoring system.

5.2 Student Mentoring

There have been numerous studies around the effectiveness of student mentoring within higher education institutions, for example [11 and 12], and some innovative institutions are beginning to implement mentoring as part of the overall strategy to improving retention and success of students. These tend to be focused on social issues as a way of helping students cope with the demands faced when embarking on their undergraduate studies, for example, the use of induction activities to help students familiarise themselves with the campus, or develop self-directed study techniques is widespread. Although these types of activity can be conducted by staff, they are much more successful when conducted as part of a student mentoring programme [13]. One of the main benefits of this type of system is that experienced students can share their experiences of university life with new students. This in turn fosters a sense of belonging. Although these schemes have proven very successful in many institutions and although some subject level mentoring schemes do exist, there still remains a requirement for more subject specific student mentoring programmes. Furthermore, setting up cross-institutional subject support systems has the potential to provide huge benefits in terms of both social and academic interaction. Being able to gain support from a much wider range of students, following different courses with different approaches to learning, has the potential to create a much more effective student mentoring system as well as harnessing the knowledge of G&T students. To this end, Lincoln is developing a 'student expert' system.

The student expert system is designed to achieve three main objectives.

- To harness the knowledge of gifted and talented students in providing student-to-student support.
- To promote support between first and second year students as a way of increasing success of not only first year students but second year students also.
- To encourage cross-institutional support.

The system works by identifying particular student experts either through diagnostic tests, previous assessments, or by the student's own assessment. Judgements are also made by teaching staff as to the suitability of experts based on other criteria such as communication skills, approachability etc. Student experts are drawn from across the institution with the aim of providing several experts in each topic area. Following a diagnostics test, learners are given the option to contact a student expert to gain support in areas of weakness. Support remains anonymous to prevent known negative effects of competition and effects on self-esteem, for example see Croft [14].

An issue that institutions often face within student mentoring programmes is that of how to inspire students to become mentors and how to ensure they are fully engaged in the support they offer? The solution comes through competition and recognition. Students who receive recognition for their work also experience an increase in self-esteem, self-confidence and affirmation of professional competence [15]. Lincoln's student expert system is underpinned through a student rating system and institutional recognition. The student receiving support from the student expert will be required to rate the answer and provide a feedback score for the expert based on factors such as response time, level of knowledge, quality of explanations etc. The feedback rating on a scale of 1-5, will then be allocated to the student expert's overall score. At the end of each semester, the top 5 ranked student experts are then identified and rewarded accordingly. This will not only give institutional wide recognition to students for their efforts in student mentoring but will also encourage other experts to provide the best support possible.

6. Conclusion

This paper has outlined a current novel approach to mathematics support adopted by the Lincoln School of Engineering. Through this approach it has been shown that there is a marked increase in student retention compared to national benchmark figures. Furthermore, it has shown that there is an increase in student success backed up by this retention data and an increase in student engagement measured through regular student feedback. The paper has then extended this proven approach through the use of on-line diagnostic testing as a more effective method of formative assessment and more accurate way of identifying individual support requirements. Secondly, a student expert system is being developed to encourage student-to-student mentoring and harness knowledge of those gifted and talented students often overlooked by higher education institutions and to allow further consolidation and review of material for second year students. It is expected that, based on the success of the current system, this will enhance retention rates and student success and engagement further and become the basis for a much more informed and structured mathematics support system. An evaluation of the enhanced system will be presented in a future paper.

References

1. Roberts, Sir G., The supply of people with science, technology, engineering and mathematics skills, April 2002

2. Perkin, G., and Croft, A. C., Mathematics Support Centres – the extent of current provision, *MSOR Connections* May 2004 Vol. 4 No. 2

3. Perkin, G., Lawson D., and Croft, T. (2012) *Mathematics Learning Support in Higher Education: the extent of current provision in 2012*. Available from http://sigma-network.ac.uk

4. Lawson, D., Croft, T., and Halpin, M., (2003) *Second edition of a guide for those interested in the establishment and development of Mathematics Support Centres in institutes of higher education*, http://www.mathscentre.ac.uk

5. Mac an Bhaird, C., Morgan, T. and O'Shea, A. (2009) The impact of the mathematics support centre on the grades of first year students at the National University of Ireland, Maynooth, *Teaching Mathematics and its applications*, 28, 117-122.

6. Symonds, R., Lawson, D., and Robinson, C. R (2008) Promoting student engagement with mathematics support, *Teaching Mathematics and its applications*, 27 (3) 140-149

7. Patel, C and Rossiter, A (2010), *Encouraging engagement with Mathematics and the available support* (CETL MSOR conference, Birmingham, 6 & 7 September).

8. Engineering Council (2000), Measuring the Mathematics Problem

9. Department for Children (2008), Schools and Families, The Assessment for Learning Strategy

10. Felder, R., and Brent R., (2004) *The ABC's of Engineering Education: ABET, Bloom's Taxonomy, Cooperative Learning, and so on*, North Carolina State University/Education Designs, Inc.
http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Papers/ASEE04(ABCs).pdf

11. Lee M-L., and Bush T., Student Mentoring in higher education: Hong Kong Baptist University, *Journal of Mentoring and Tutoring: Partnership in Learning* 2003 Vol. 11 No. 3

12. Terrion J L., and Leonard D., *Journal of Mentoring and Tutoring* May 2007 Vol. 15 No.2 Pages 149-164

13. Macintosh K A., The Role of Student to Student Mentoring in Induction, The STAR Project 2006, University of Ulster, Coleraine, Northern Ireland

14. Croft, T., (2008), *Towards a culture of data collection an analysis in mathematics support centres*. Presented at the 3rd Irish Workshop on Mathematics Learning and Support Centres, NUI Maynooth, http://www.ndlr.ie/mshe/?cat=13

15. Collins, H., Mentoring Veterinary Students, *Journal of Veterinary Medical Education* 2005 Vol. 32 No. 3